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Effect of clipping on the development of roots and tops in various grass seedlings

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EFFECT OF CLIPPING ON THE DEVELOPMENT OF ROOTS AND TOPS IN VARIOUS GRASS SEEDLINGS

by

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INTRODUCTION

The study reported here deals with the effect of different intensities of clipping on the development of roots and tops of various grass seedlings. The establishment and yield of grasses depend to a large extent upon the manner and frequency with which the tops are removed. Undesirable species increase in native pastures and range lands when there is early grazing and overstocking (6)*. Grazing is a more or less destructive process because of the fact that it periodically removes much of the photosynthetic area and when such an abrupt decrease in photosynthetic activity takes place there is a corresponding decrease in the rate of root growth. Hence drouth killing, winter killing, decreased yield, and lowered vitality result from the over utilization of forage. While a good many general observations have been made upon the relation of harvesting methods to the vigor and yield of grass land and definite data from experiments on a rather limited number of grass species are available, there still is a definite need for more experimental work along this line.

*Numbers in parenthesis refer to the list of references given in this paper under the heading, Literature Cited.

HISTORICAL

A review of the literature reveals that considerable work has been done upon the effect of removal of the photosynthetic area upon the growth of tops. All of the investigations show that vigor and yield of the vegetation vary inversely with the intensity of clipping. Not so much work has been done to show the effect of clipping upon root development. Most of the data shows that root development also varies inversely with the frequency of clipping.

Frequent mowing of several cultivated species reduced the yield (4) to one-fourth normal. Stipa comata disappeared entirely under frequent harvesting (13) and various other grasses showed lowered vitality.

The removal of the herbage four or more times in a season resulted in a sharp decline in yield (12) and in marked shortage of the life of the vegetation.

McCarty (9), working in Colorado, found that when quadrats of Agropyron smithii were harvested four times during one year, they yielded 84 per cent of their calculated value during the second year of treatment. Quadrats harvested seven and eight times in one year yielded respectively, 50 per cent and 40 per cent of their estimated values during the second year.

Aldous (2), by clipping at two week intervals in Kansas, found that density of the vegetation decreased about 60 per cent in three seasons. Clipping at three week intervals resulted in only a 13 per cent reduction.

Cutting when plants are mature gives more reserve food and higher yield with less winter killing and longer life of crop whether grass or alfalfa (1).

The nutritive value of pasture herbage under fertilization and abundant rainfall is independent of cutting period (14).

Any retardation in the root system of a newly established seedling may be considered as a deciding factor as to whether the plant is to live or die.

Any cropping (12) which results in the reduction of the aerial growth of grasses is reflected in the root development and the quantity of food stored in underground parts.

Frequent and immature cutting of bluegrass reduced the amount of rhizomes and root growth when compared to bluegrass cut at maturity (5).

Pierre and Bertram (10) found that the roots of Kudzu plants cut six times per season decreased in weight during a period of two years, while those from plants receiving four cuttings increased 150 per cent. The reserves of starch and nitrogen were less than half as great in the roots of plants receiving six cuttings as in those receiving four.

Harrison (7) clipped grasses at various heights and concluded that the amount of roots increased with the height to which the grasses were clipped.

According to Biswell (3) diameters of both roots and stele as well as number of ducts were decreased as a result of clipping.

Robertson (11) found that in general root penetration of grass seedlings was retarded from 35 to 62 per cent as a result of frequent clipping and that dry weight of the roots was reduced from 66 to 98 per cent.

Most of the investigators agree that the more frequent and drastic the clipping the less is the yield of tops and roots. There is one exception, however. Laird (8) states "The largest and deepest root systems of sod forming grasses are not necessarily associated with the best and most vigorous top growth." Mowing of Centipede and Bermuda grasses increased the root growth.

EXPERIMENTAL

Method of Procedure

The seeds of four important range grasses were used in this experiment. They were blue grama grass (Bouteloua gracilis), California brome (Bromus carinatus), bluestem (Agropyron smithii) and slender wheat grass (Agropyron pauciflorum).

The soil used was a fertile loam. This was mixed with one-fourth part of dry sand to make root extraction easier.

Fourteen boxes were used each being 11.5 inches wide, 17 inches long, and 9.5 inches deep. Each box was divided into two parts each part being 8.5 inches wide by 11.5 inches long and one species planted in each part. Also fifty-six four inch drain tiles were used, each being 12 inches long. These were used to get data on the roots and no record was kept of top growth. A record was kept of the height and weights of the tops in the boxes, however, and data taken on the roots in the boxes as well. The boxes were filled February 6, the soil being well compacted in each. There were two series for each clipping treatment and one control for each species. The tiles were filled February 15. There were four series for each clipping treatment and two controls for each species.

A light sprinkling for seven days following planting insured rapid germination. On the seventh day after planting the height of the seedlings was taken and at regular intervals thereafter.

It was decided to simulate grazing by removing the tops of the grasses by clipping at definite intervals of time. The heavy clipping series had the tops clipped every 10 days, moderate clipping series every 20 days, and the deferred series was clipped twice, both times near the end of the experiment.

All species were clipped to within 1.5 cm. of the ground. The tops were dried in an electric oven for 24 hours at about 80°C. and then weighed to the nearest 0.01 gm.

Comparisons of tops included dry weight at each clipping, total dry weight, total height and ability to recover under different systems of clipping.

Comparisons of roots included average length and total dry weight. The soil was removed from the roots by washing with a small stream of water and allowing the muddy water to run through a sieve to catch any roots that might have broken off.

This experiment ran for about 120 days and was carried on in a greenhouse.

The temperature of the greenhouse averaged about 72°F. but varied from 60°F. to 90°F. during the course of the experiment. The humidity was high at all times. The variation in moisture content of the soil was from 23.1 per cent to 31.3 per cent.

Results

Bouteloua gracilis

The seedlings of grama grass were clipped when three weeks old in both the boxes and tiles. They were then clipped every 10 days in the heavy clipping series and every 20 days in the moderate clipping series. In the deferred clipping series the plants were allowed to make considerable growth before clipping. Only two clippings were made in this series. They were made during the last three weeks of the experiment. At the time of the first clipping in the heavy and moderate clipping series the plants were 5.5 cm. tall in the boxes. Thus there was an average daily growth of about 2.7 mm. The deferred clipping series was clipped when the plants were about 24.5 cm. tall. The plants were 100 days old and had made an average daily growth of 2.4 mm.

A comparison of growth rates after each clipping at 10 day intervals shows that the second, fourth, fifth, eighth, and ninth cuttings stimulated growth slightly while the other clippings showed a slight decrease (fig.1). The eleven clippings show that recovery after each clipping remains about the same. In the plants that were clipped every 20 days, the second and fifth cuttings stimulated growth somewhat, while the rest of the clippings showed a slight decrease in growth. But as in the heavy clipping series the recovery remains about the same (fig. 2). In the deferred clipping series only two cuttings were made, one on May 24 and the last one on June 9, so the only comparison of growth is for total height increase. The total increase in height for the seventeen weeks was 28.5 cm. for the unclipped plants. The heavily clipped plants showed a total height increase of 46 cm., the moderately clipped plants showed a total height

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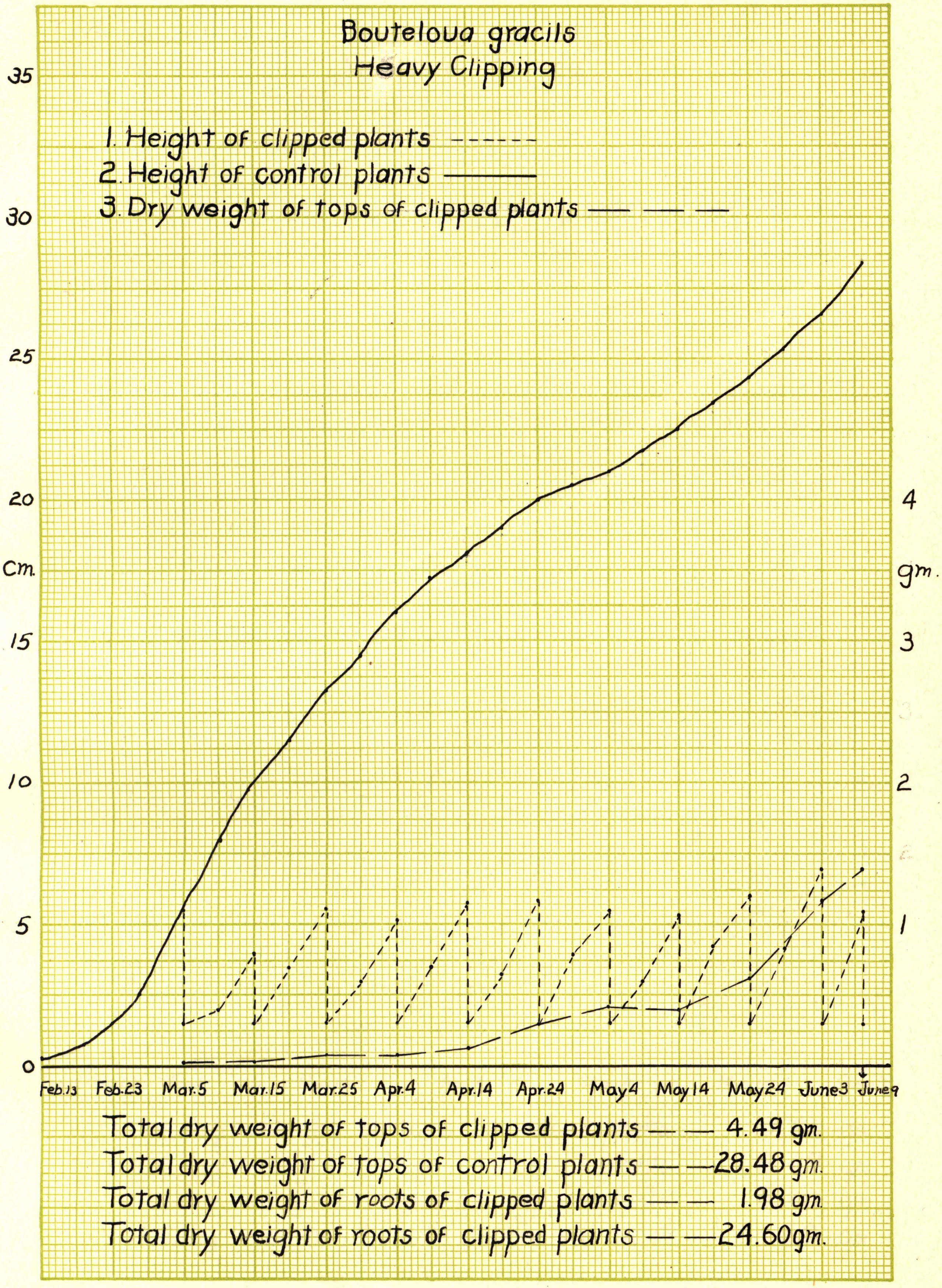

Fig. 1. Growth of tops of Bouteloua gracilis, heavy clipping.

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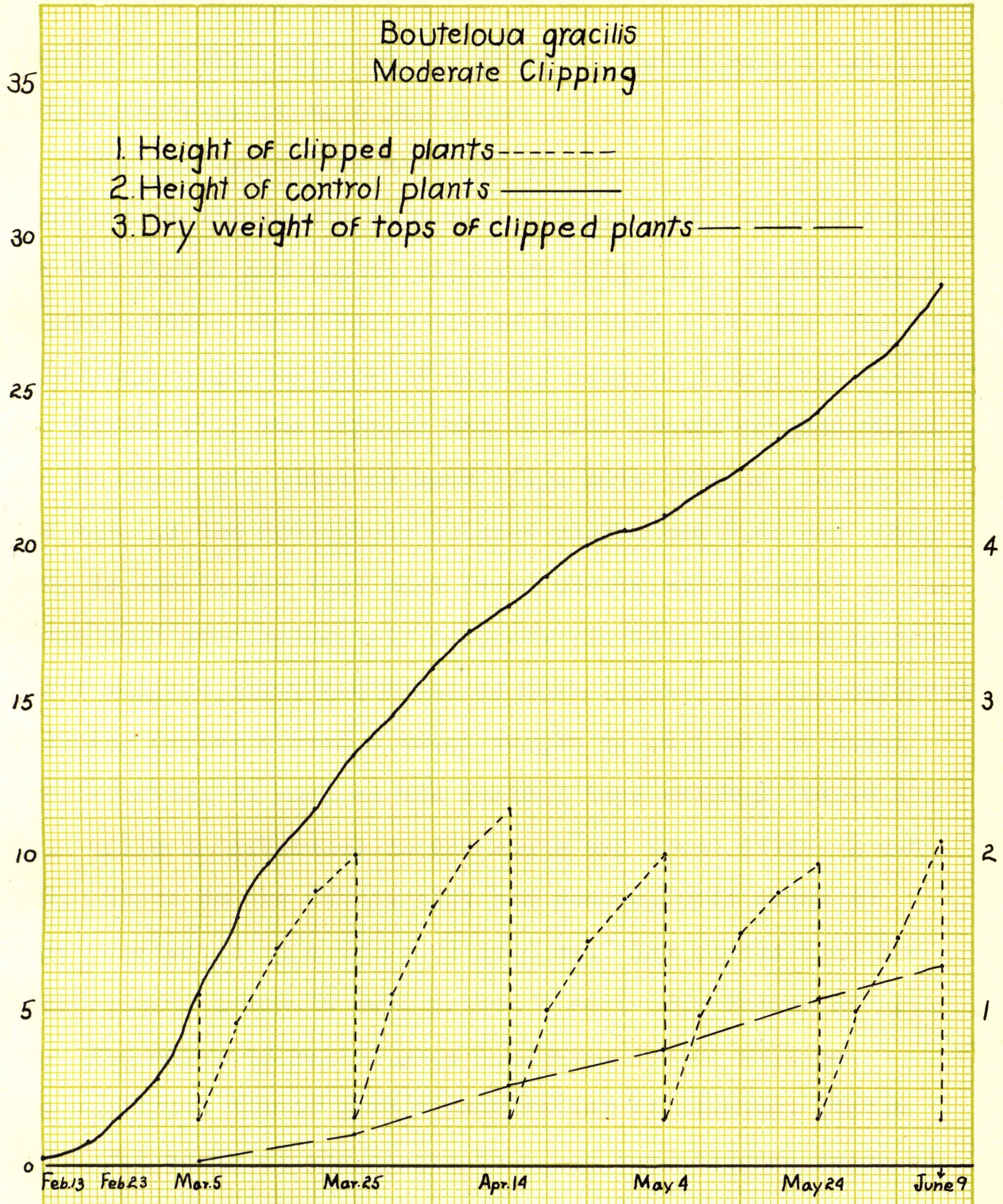

Total dry weight of tops of clipped plants--- 3.85 gm.
Total dry weight of tops of control plants--- 28.48 gm.
Total dry weight of roots of clipped plants--- 5.40 gm.
Total dry weight of roots of control plants--- 24.60 gm

Fig. 2. Growth of tops of Bouteloua gracilis, moderate clipping.

increase of 49.5 cm., and the deferred series gave a total height increase of 41.5 cm.

The dry weights of the tops showed an almost steady increase in the plants that were clipped every 10 days except for the fourth and eighth clippings (fig. 1). In moderately clipped plants there was a steady increase (fig. 2). The total dry weight of tops of heavily clipped plants was 4.49 gm. (table 1). The tops of the control plants weighed 28.48 gm. or about six times as much (fig. 10). The dry weight of the tops of the moderately clipped plants was 3.85 gm. This drop is due to the fact that fewer plants were present in the boxes that were moderately clipped. In this case the control plant weighed about 6.5 times as much (table 1). The deferred clipping series showed a total weight of 19.6 gm. or about three-fourths as much as the control tops weighed (table 1).

Quite a difference in the roots was found (figs. 9 and 10). Those on the plants that had been clipped every 10 days penetrated to a depth of 14.4 cm. The plants that had been clipped every 20 days showed a root penetration of 21.2 cm. The deferred series gave a penetration of 27.2 cm. The unclipped plants gave a penetration of 31.2 cm. (table II). The roots of the plants that had been clipped every 10 days were small and very few side roots were present, in the moderately clipped plants the roots were a little longer and more fibrous. Not so much difference was noted between the deferred and control plants. The total dry weight of the roots

TABLE I. SHOWING DRY WEIGHT OF TOPS IN GRAMS AT EACH CLIPPING AND THE TOTAL DRY WEIGHT IN GRAMS IN BOXES

Heavy Clipping Series

Series	Species	Mar. 5	Mar. 15	Mar. 25	Apr. 4	Apr. 14	Apr. 24	May 4	May 14	May 24	June 3	June 9	Total weight
1	Ag.pauc.	1.64	.50	.41	.23	.16	.20	.20	.01	0	0	0	3.35
2	" "	2.41	.70	1.15	.50	.22	.19	.27	.08	.02	.01	0	5.55
1	Ag. sm.	.50	.29	.30	.25	.15	.06	.09	.01	.01	.01	.01	1.65
2	" "	.41	.21	.16	.12	.16	.01	.01	.01	0	0	0	1.09
1	Br. car.	1.21	.15	.11	.08	.02	.09	.13	.12	.13	.02	.02	2.08
2		1.20	.49	.24	.08	.02	.08	.13	.10	.11	.02	.02	2.49
1	B. gr.	.01	.02	.08	.06	.20	.28	.34	.30	.60	1.17	1.29	4.35
2	" "	.01	.03	.10	.07	.09	.35	.45	.43	.69	1.19	1.23	4.63

Moderate Clipping Series

Series	Species	Mar. 5	Mar. 25	Apr. 14	May 4	May 24	June 9	Total weight
1	Ag. pauc.	1.92	2.03	2.31	2.72	.85	1.34	11.17
2	" "	2.21	3.17	2.68	2.09	.11	.43	10.69
1	Ag. sm.	.30	1.31	1.94	.71	.09	.11	4.46
2	" "	.35	1.45	2.40	1.01	.45	.33	5.99
1	Br. car.	1.29	3.67	5.54	2.70	.76	1.60	15.56
2	" "	1.02	2.85	3.41	2.81	2.01	3.15	15.25
1	B. gr.	.01	.20	.41	.72	1.23	1.40	3.96
2	" "	.01	.21	.60	.79	.92	1.22	3.75

Deferred Clipping Series

Series	Species	May 24	June 9	Total weight
1	Ag. pauc.	14.86	17.45	32.31
2	" "	21.11	23.02	44.13
1	Ag. sm.	22.60	14.07	30.67
2	" "	16.03	13.20	29.23
1	Br. car.	24.82	23.45	48.27
2	" "	22.30	20.49	42.79
1	B. gr.	7.58	15.26	22.84
2	" "	5.91	10.47	16.38

Controls

Species	Total weight
Ag. pauc.	49.35
Ag. sm.	42.50
Br. car.	51.27
B. gr.	28.48

TABLE II. COMPARISON OF ROOT LENGTHS AND WEIGHTS UNDER DIFFERENT METHODS OF CLIPPING IN BOXES

Agropyron pauciflorum

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	10.3 cm.	1.6 gm.
2	"	11.1	1.61
1	Moderate	13.3	9.1
2	"	15.4	7.58
1	Deferred	24.8	61.61
2	"	27.5	65.90
Control	Control	33.6	66.1

Agropyron smithii

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	9.4 cm.	.99 gm.
2	"	8.2	.82
1	Moderate	15.5	3.19
2	"	13.6	3.81
1	Deferred	25.5	47.20
2	"	26.4	43.20
Control	Control	32.1	53.73

Bromus carinatus

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	12.2 cm.	.67 gm.
2	"	9.3	.79
1	Moderate	17.6	5.87
2	"	20.2	6.21
1	Deferred	32.4	58.37
2	"	34.3	53.13
Control	Control	36.3	62.20

Bouteloua gracilis

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	12.3 cm.	1.87 gm.
2	"	16.9	2.10
1	Moderate	22.8	5.67
2	"	19.4	5.13
1	Deferred	28.3	22.71
2	"	26.2	18.10
Control	Control	31.2	24.60

in heavy clipping was 1.98 gm. while those of the unclipped plants weighed 24.6 gm. or over 12 times as much (fig. 10); the roots of the plants that were clipped every 20 days weighed 5.4 gm. or about a fifth as much as the control plants. In the deferred plants the roots weighed 20.4 gms. For comparisons of lengths and weights of the roots in the tiles, see table III.

There was one hundred per cent survival of the plants under all methods of treatments (table IV).

Bromus carinatus

The seedlings were 16 cm. tall when first clipped in the boxes. They were three weeks old when clipping was started in both the boxes and the tiles. One series was clipped every 10 days, another every 20 days and two clippings were made in the deferred clipping series. Both of these clippings were made during the last three weeks of the experiment. The plants had made an average daily growth of 8 mm. per day when clipping was started in both the heavy and moderate clipping series. The plants were 32.5 cm. when clipped in the deferred series or an average daily growth of 3.25 mm.

After the second cutting was made in the heavy clipping series there was a gradual increase in recovery up to the high point at May 14 from there the growth rate dropped (fig. 3). In the plants that were clipped every 20 days, the

TABLE III. COMPARISON OF ROOT LENGTHS AND WEIGHTS UNDER DIFFERENT METHODS OF CLIPPING IN TILES

Agropyron pauciflorum

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	10.2 cm.	.34 gm.
2	"	15.1	.32
3	"	14.1	.31
4	"	17.3	.29
1	Moderate	25.8	1.69
2	"	22.8	1.91
3	"	20.2	1.62
4	"	25.3	1.70
1	Deferred	40.4	12.45
2	"	38.2	12.31
3	"	41.6	11.85
4	"	39.2	12.30
Control	Control	44.6	21.71
Control	Control	42.2	19.13

Bromus carinatus

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	15.4 cm.	.25 gm.
2	"	12.6	.19
3	"	16.7	.24
44	"	10.4	.22
1	Moderate	26.1	1.34
2	"	25.7	1.06
3	"	21.9	1.25
4	"	23.8	1.19
1	Deferred	38.9	7.12
2	"	37.2	5.87
3	"	39.6	6.09
4.	"	40.1	5.45
Control	Control	39.3	11.00
Control	Control	42.1	10.50

Agropyron smithii

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	14.1 cm.	.13 gm.
2	"	10.2	.17
3	"	9.9	.16
4	"	10.4	.14
1	Moderate	19.2	..30
2	"	17.8	.24
3	"	16.3	.20
4	"	15.8	.27
1	Deferred	33.3	5.89
2	"	38.6	6.02
3	"	30.1	5.73
4	"	35.2	5.61
Control	Control	37.6	6.23
Control	Control	43.4	5.92

Bouteloua gracilis

Series	Method of clipping	Length of roots	Weight of roots
1	Heavy	19.1 cm.	.13 gm.
2	"	21.2	.11
3	"	18.0	.09
4	"	22.2	.15
1	Moderate	25.1	.42
2	"	30.3	.46
3	"	27.1	.34
4	"	29.4	.51
1	Deferred	33.7	2.20
2	"	32.8	2.07
3	"	31.4	2.53
4	"	32.2	2.12
Control	Control	34.2	3.84
Control	Control	37.3	3.59

TABLE IV. PER CENT OF PLANTS SURVIVING AT EACH CLIPPING TREATMENT

Heavy Clipping Series

Series	Species	Per cent of plants surviving at each clipping										
		Mar. 5	Mar. 15	Mar. 25	Apr. 4	Apr. 14	Apr. 24	May 4	May 14	May 24	June 3	June 9
1	Ag. pauc.	100	96	93	90	70	54	32	5	0	0	0
2	" "	100	95	90	82	55	45	34	10	4	2	0
1	Ag. sm.	100	99	93	87	75	46	30	21	11	5	3
2	" "	100	97	91	79	51	24	11	6	0	0	0
1	Br. car.	100	93	67	49	43	42	40	35	31	16	10
2	" "	100	90	73	57	53	51	49	40	38	18	7
1	B. gr.	100	100	100	100	100	100	100	100	100	100	100
2	" "	100	100	100	100	100	100	100	100	100	100	100

Moderate Clipping Series

Series	Species	Per cent of plants surviving at each clipping					
		Mar. 5	Mar. 25	Apr. 14	May 4	May 24	June 9
1	Ag. pauc.	100	90	84	75	52	20
2	" "	100	92	86	70	45	14
1	Ag. sm.	100	90	85	76	45	22
2	" "	100	90	82	71	49	27
1	Br. car.	100	94	87	72	60	51
2	" "	100	91	81	74	66	55
1	B. gr.	100	100	100	100	100	100
2	" "	100	100	100	100	100	100

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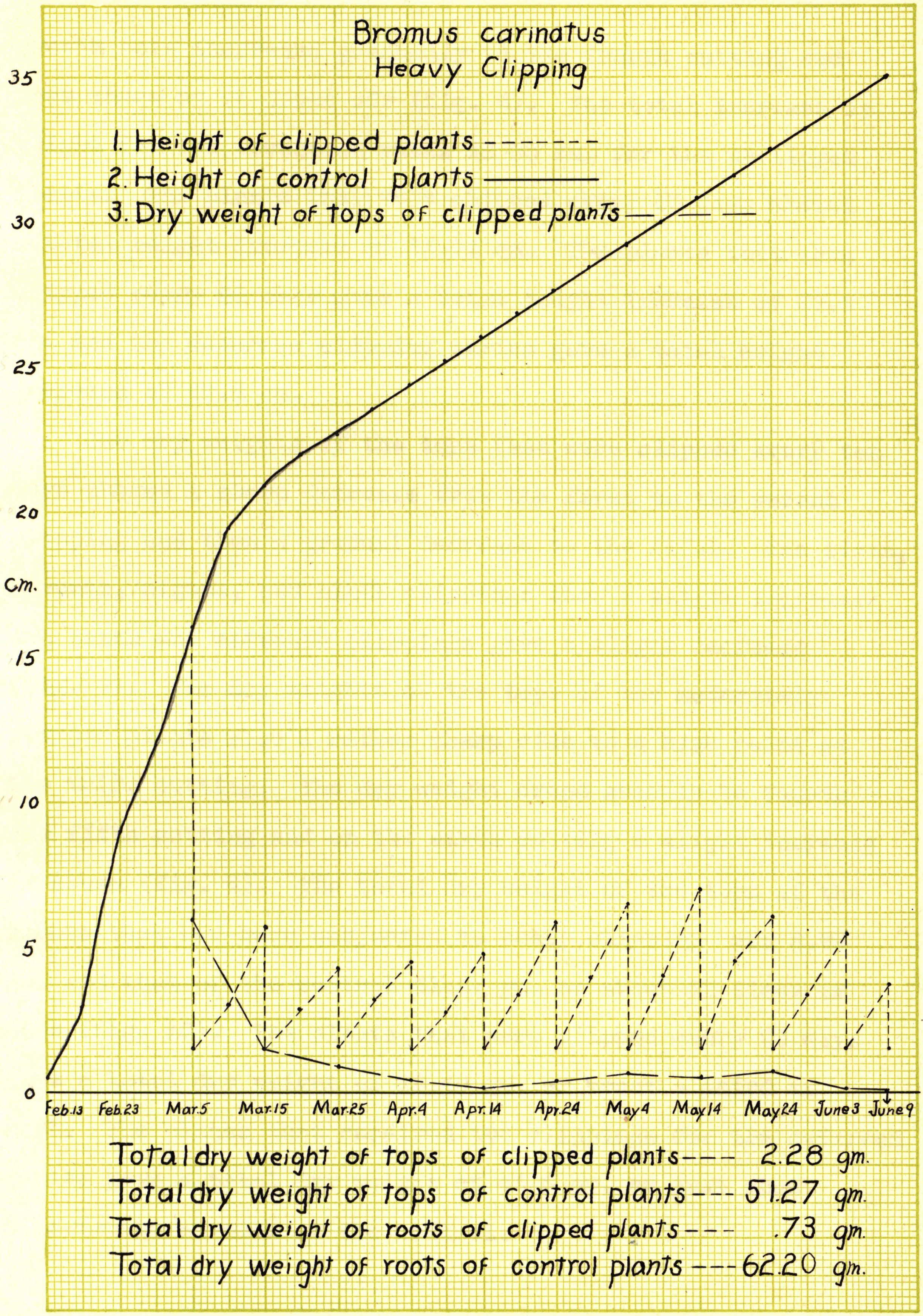

Fig. 3. Growth of tops of Bromus carinatus, heavy clipping.

growth rate increased gradually to the fourth cutting and from there on it drops off (fig. 4). The total increase in height for the seventeen weeks is 35 cm. for the unclipped plants. The plants that were clipped every 10 days showed a total height increase of 53.75 cm. The plants that were clipped every 20 days gave a total height increase of 87.5 cm. and the deferred clipping series gave a total height increase of 49.5 cm.

The dry weights of the tops that were clipped every ten days showed a sharp decrease from the first to the second clipping and then a gradual decrease to the fifth. The sixth, seventh, eighth, and ninth clippings show a slight increase and tenth and eleventh clippings give a slight decrease (fig. 3). The dry weights of the tops of the moderately clipped plants show a rather sharp rise to a high point at the third cutting. The dry weight drops sharply to fourth and fifth cutting and on the sixth cutting a slight increase is shown (fig. 4). The total dry weight of the tops of the plants that had been subjected to heavy clipping was 2.28 gm. and that of the control 51.27 gm. or about 23 times as much (fig. 10). The plants that were clipped every 20 days gave a total dry weight of 15.40 gm. or about a third as much. The plants that received two clippings for the deferred series gave a total dry weight of 45.5 gm. or just about nine-tenths as much as the control.

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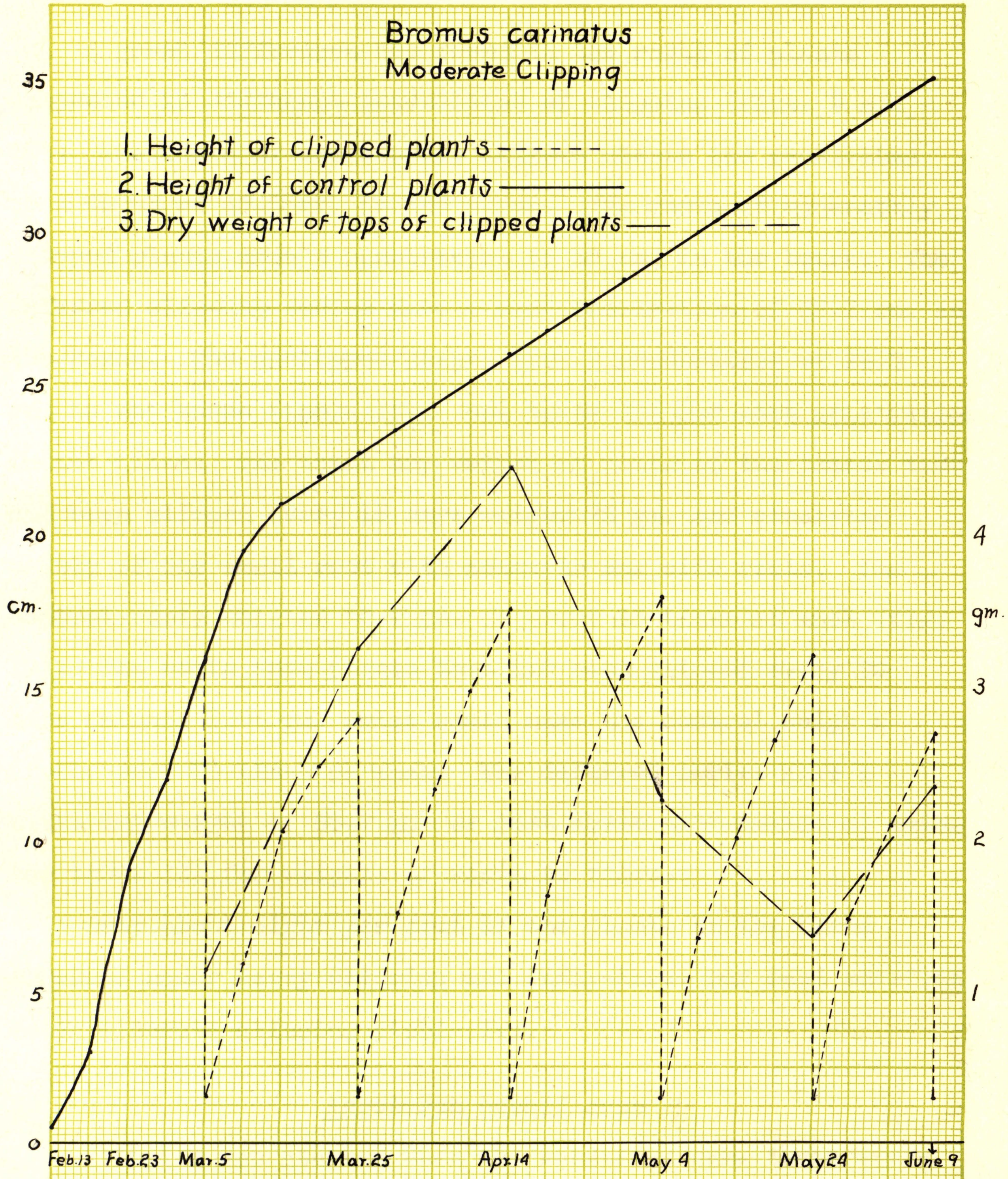

Total dry weight of tops of clipped plants --- 15.40 gm.
Total dry weight of tops of control plants --- 51.27 gm.
Total dry weight of roots of clipped plants --- 6.04 gm.
Total dry weight of roots of control plants --- 62.20 gm.

Fig. 4. Growth of tops of Bromus carinatus, moderate clipping.

A great difference was found in the roots of plants subjected to different intensities of clipping (figs. 9 and 10). The roots of the heavily clipped plants had penetrated to a depth of 10.7 cm. in the boxes. The roots of moderately clipped plants gave a penetration of 19 cm. in the boxes. The deferred clipping series gave a root penetration of 33.3 cm. in the boxes. The unclipped plants gave a penetration of 36.3 cm. in the boxes (table II). See table III for root penetration in the tiles. The total dry weight of roots of the plants that had been clipped every 10 days weighed .73 gm. and consisted mainly of one small root with scarcely any side roots. The control roots weighed 62.2 gm. or about 85 times as much (fig. 10). The roots from plants that had been clipped every 20 days weighed 6.04 gm. which would make the control weigh a little over 10 times as much. The deferred series gave a total dry weight of 55.7 gm. or just about nine-tenths as much. See table III for weights of roots in tiles.

Only about eight per cent of the plants in the boxes survived under heavy clipping and fifty-three per cent survived under moderate clipping (table IV).

<u>Agropyron pauciflorum</u>

Clipping was started when the seedlings were three weeks old in both the boxes and tiles. The plants were 15 cm. tall in the boxes at the time of the first clipping in the heavy and moderate series. They had made an average daily growth of

7.5 mm. The deferred clipping plants were about 29.5 cm. when clipped. The plants were 100 days old and had made an average daily growth of 2.9 mm.

The first, fourth, and fifth cuttings in the heavy clipping series stimulated growth somewhat. The second, third, and sixth clippings showed a slight decrease, while the seventh, eighth, ninth, and tenth cuttings showed a definite decrease. The total result of the eleven cuttings is a gradual inhibition of growth. With the plants that were clipped every 20 days, recovery is shown to be about the same after each clipping. The total increase in height for the seventeen weeks was 32 cm. for the unclipped plants. The heavily clipped plants showed a total height increase of 49.2 cm., the plants that were clipped every 20 days showed a total height increase of 70 cm. and the deferred series gave a total height increase of 43 cm.

The dry weight of the tops in the plants that were clipped every 10 days showed a sharp decrease the second cutting. A slight increase was noted for the third and seventh cuttings. The rest of the cuttings showed a decrease until at the final cutting there was scarcely any growth (fig. 5). This was due to the high mortality resulting from heavy clipping (table IV). In the moderately clipped plants there was a slight increase the second cutting; the third and fourth cuttings remained about the same with a sharp decrease at the fifth cutting and

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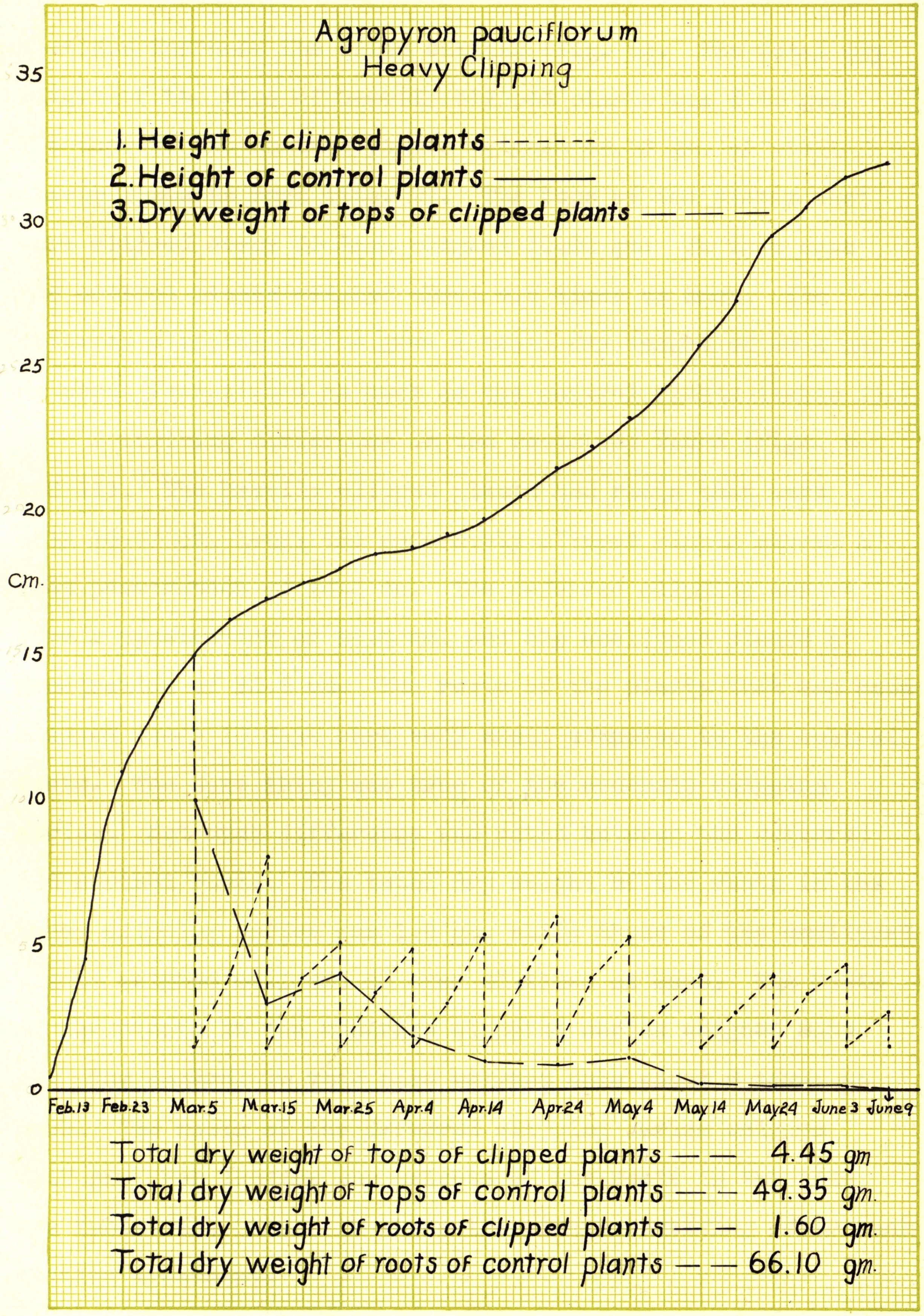

Fig. 5. Growth of tops of Agropyron pauciflorum, heavy clipping.

a slight increase the sixth cutting (fig. 6). The total dry weight of the tops of heavily clipped plants was 4.45 gm. The tops of the control plants weighed 49.35 gm. or about eleven times as much (fig. 2). The tops of the plants that were clipped every 20 days weighed 10.93 gm. In this case the control plants weighed about 4.5 times as much. The deferred clipping series gave a total dry weight of 38.2 gm. or about four-fifths as much as the control plants (table I).

A striking difference in the roots was found (figs. 9 and 11). The heavily clipped plants had roots that were only 10.75 cm. long, the moderately clipped plants showed a root penetration of 14.3 cm. The deferred clipping series gave a penetration of 26.6 cm. and the unclipped plants a penetration of 33.6 cm. The roots of the plants that had been clipped every 10 days were very small compared to the control roots. The same thing was true of the moderate clipping series. Not much difference was noted between the deferred and control roots. The total dry weight of the roots in the heavy clipping series was 1.6 gm. while those of the unclipped plants weighed 66.1 gm. or over 40 times as much. The roots of the plants in the moderate clipping series weighed 8.34 gm. The control in this case weighed only about 8 times as much. The roots of the deferred clipping series weighed 63.7 gm. For lengths and weights of the roots in the tile see table III. Table IV shows the plants surviving after each cutting treatment.

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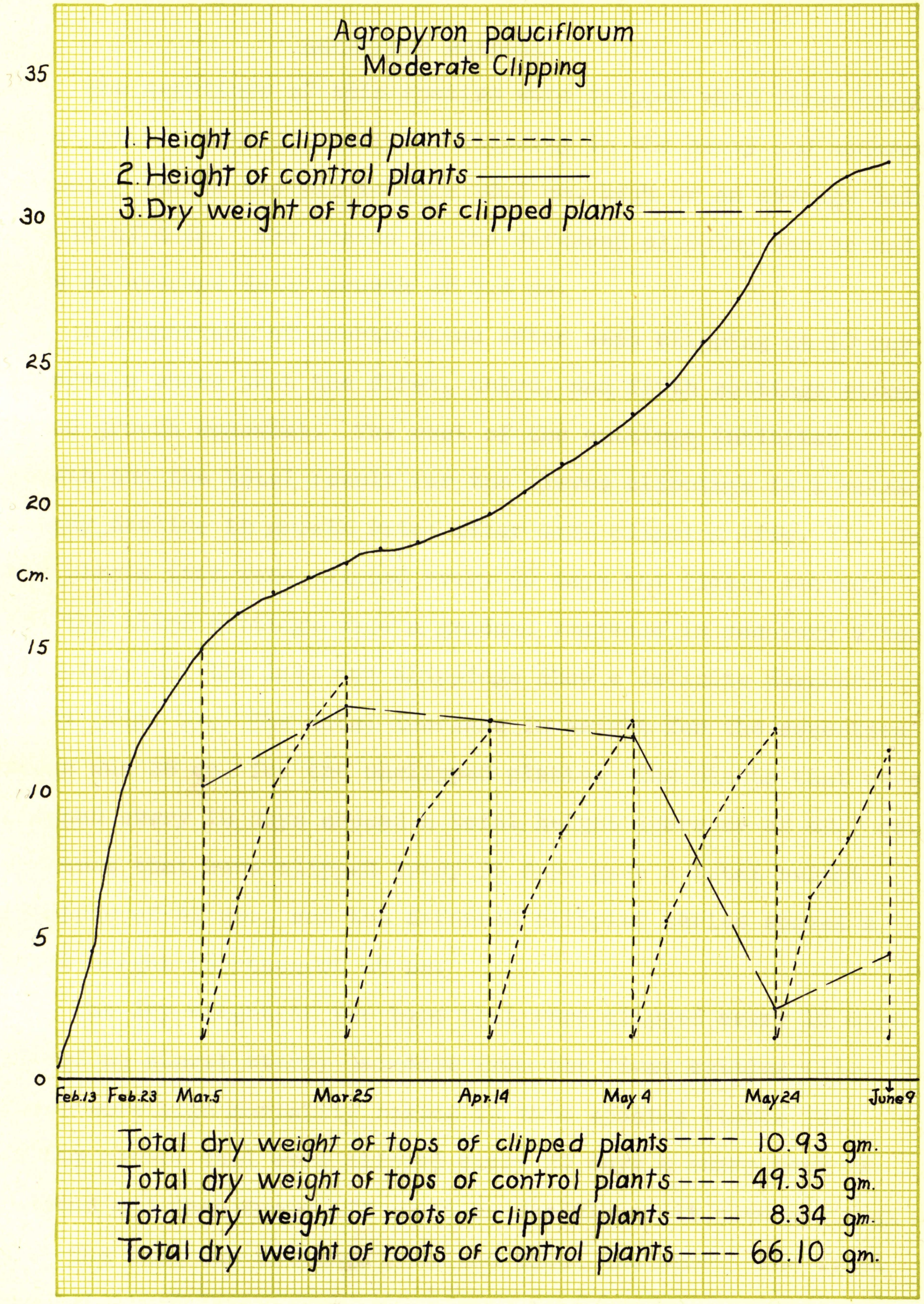


Fig. 6. Growth of tops of Agropyron pauciflorum, moderate clipping.

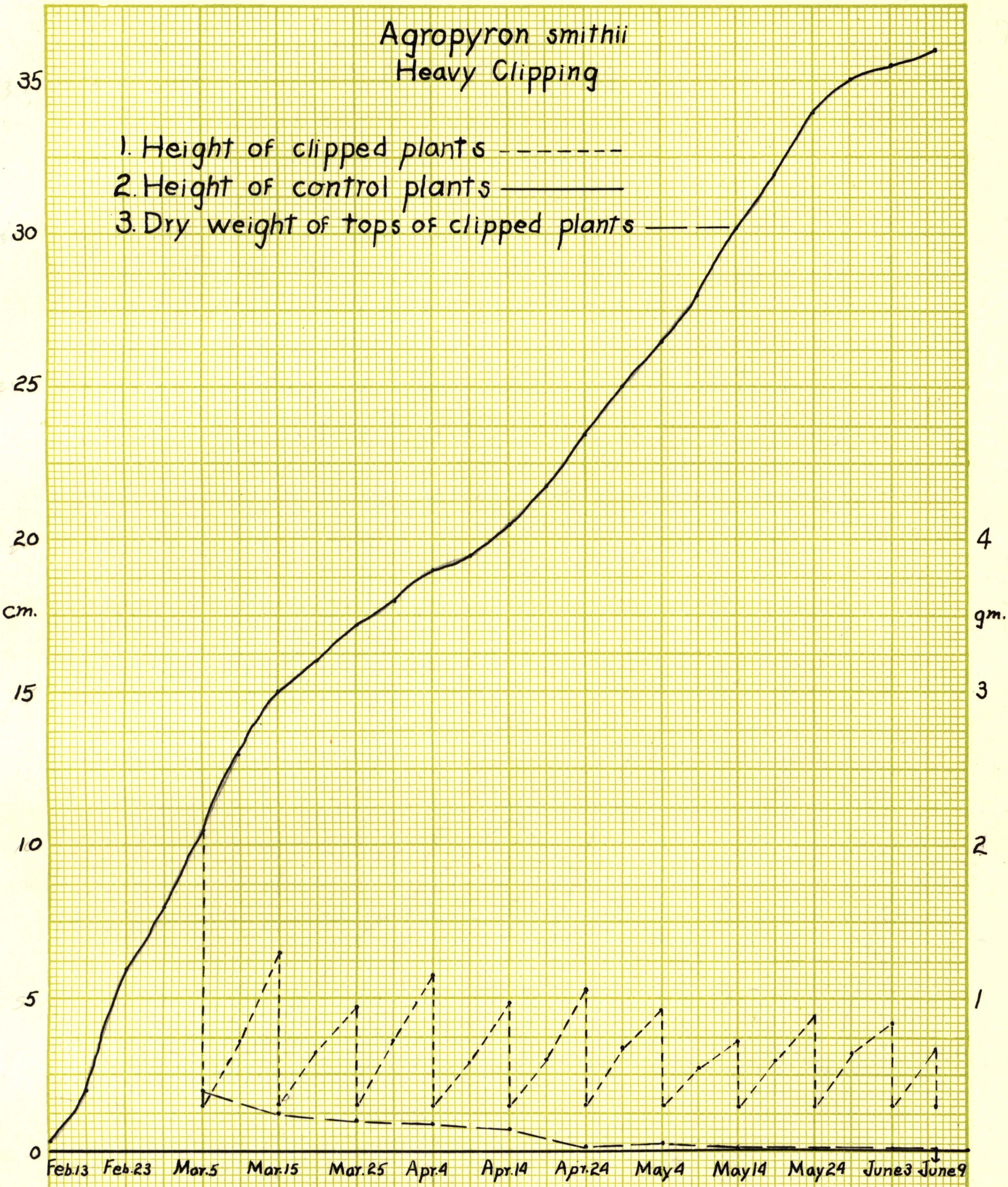
Agropyron smithii

The seedlings of this species were clipped when three weeks old. At the time of the first clipping in the heavy and moderate clipping series the plants were 10.5 cm. high or an average daily growth of 5 mm. The plants in the deferred clipping series had made an average daily growth of 3.4 mm.

A comparison of growth rates after each clipping at 10 day intervals shows that the first, third, and fifth cuttings stimulated growth somewhat. The rest of the cuttings inhibited growth and the total result for the eleven clippings is a rather steady decline in growth rates after each clipping (fig. 7). In the plants that were clipped every 20 days the first, second, and the third cuttings show a gradual increase in recovery after clipping, but the last two clippings show a definite downward trend (fig. 8). The total increase in height for the seventeen weeks was 36 cm. for the unclipped plants. The plants that were clipped every 10 days showed a total height increase of 42.7 cm., the ones that were clipped every 20 days gave a total height increase of 69 cm., and the deferred clipping series showed a total height increase of 45 cm.

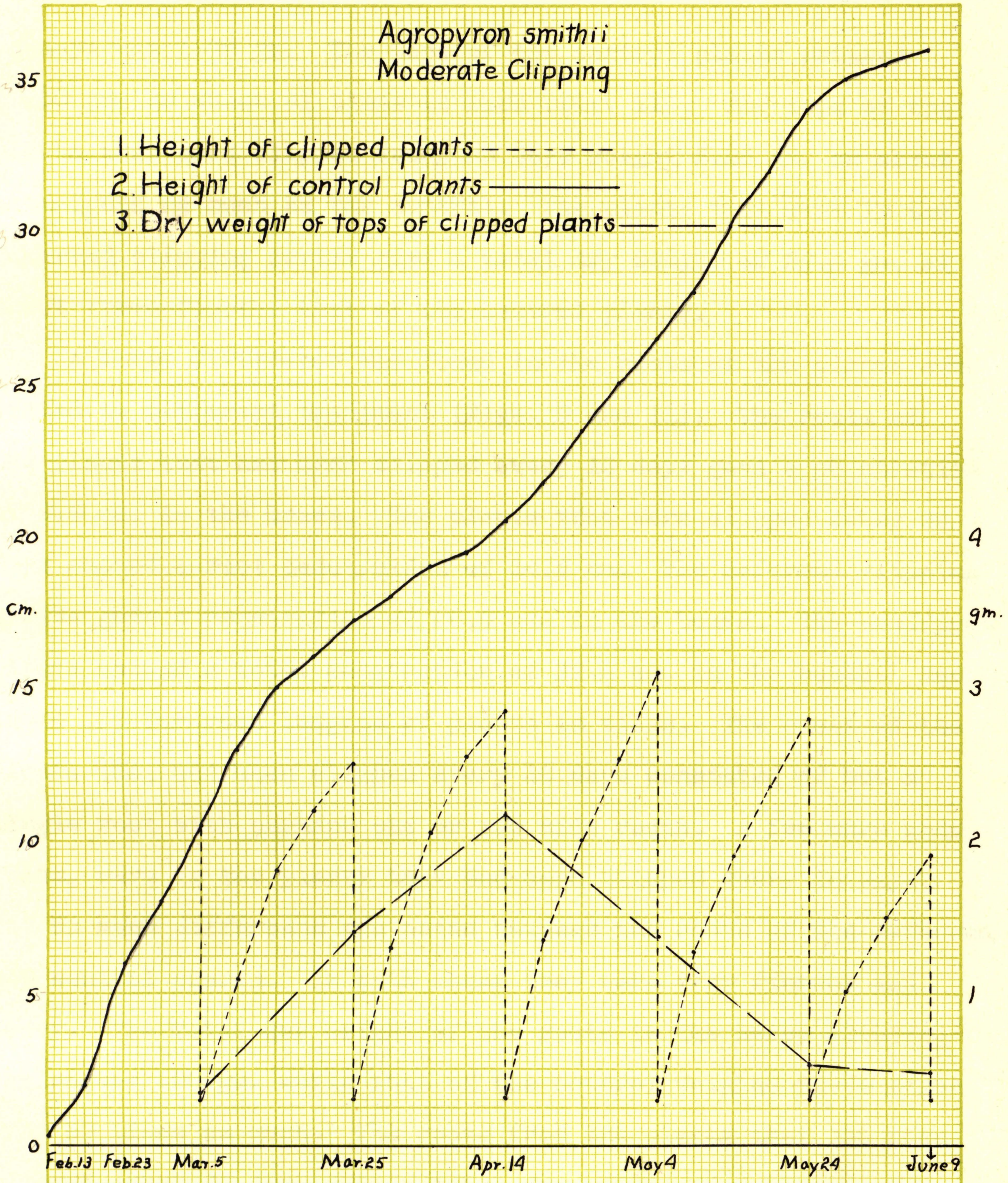
The dry weight of the tops that were clipped every 10 days showed an almost steady decrease from the first cutting (fig. 7). There were high mortality losses in this species (table IV). In the plants that were clipped every 20 days a sharp peak is reached and then drops off about as rapidly as it came up (fig. 8). The last two cuttings remained about the same. The total dry weight of the tops of the plants that had been clipped every

Form E-4



Total dry weight of tops of clipped plants --- 1.36 gm.
Total dry weight of tops of control plants --- 42.50 gm.
Total dry weight of roots of clipped plants --- .85 gm.
Total dry weight of roots of control plants --- 53.73 gm.

Fig. 7. Growth of tops of Agropyron smithii, heavy clipping.



Total dry weight of tops of clipped plants - - - 5.22 gm.
Total dry weight of tops of control plants - - - 42.50 gm.
Total dry weight of roots of clipped plants - - - 3.50 gm.
Total dry weight of roots of control plants - - - 53.73 gm.

Fig. 8. Growth of tops of Agropyron smithii, moderate clipping.

10 days was 1.36 gm. The tops of the control plants weighed 42.50 gm. or about 31 times as much (fig. 11). The tops of the plants that were clipped every 20 days weighed 5.25 gm. or about one-eighth as much as the control. The plants that were in the deferred clipping series gave a total dry weight of 32.8 gm. or about three-fourths that of the control plants.

A large difference was found in the roots of the plants subjected to different treatment (figs. 9 and 11). The roots of the plants that had been clipped every 10 days gave a penetration of 8.8 cm. in the boxes. The plants that were clipped every 20 days showed a root penetration of 14.5 cm. The deferred clipping series gave a penetration of 26.0 cm. in the boxes. The unclipped plants showed a total penetration of 32.1 cm. in the boxes. See table III for root lengths of plants in tiles. The roots of the plants that had been clipped every 10 days consisted of but a single root with perhaps one or two side roots. A few more side roots, were in the plants that had been clipped every 20 days. Not so much difference was noted between the roots of the deferred and control plants. In both cases they were very fibrous and heavy. The total dry weight of the roots in the heavy clipping series was .90 gm. while that of the control weighed 53.73 gm.or over 60 times as much. The roots from the plants that had been clipped every 20 days gave a total dry weight of 3.50 gm. In this case the control weighed about 15 times as much. The deferred series gave a total dry weight of 45.2 gm. or a little better than three-fourths as much as the control. For weights of roots in tiles see table III.

Form E-4

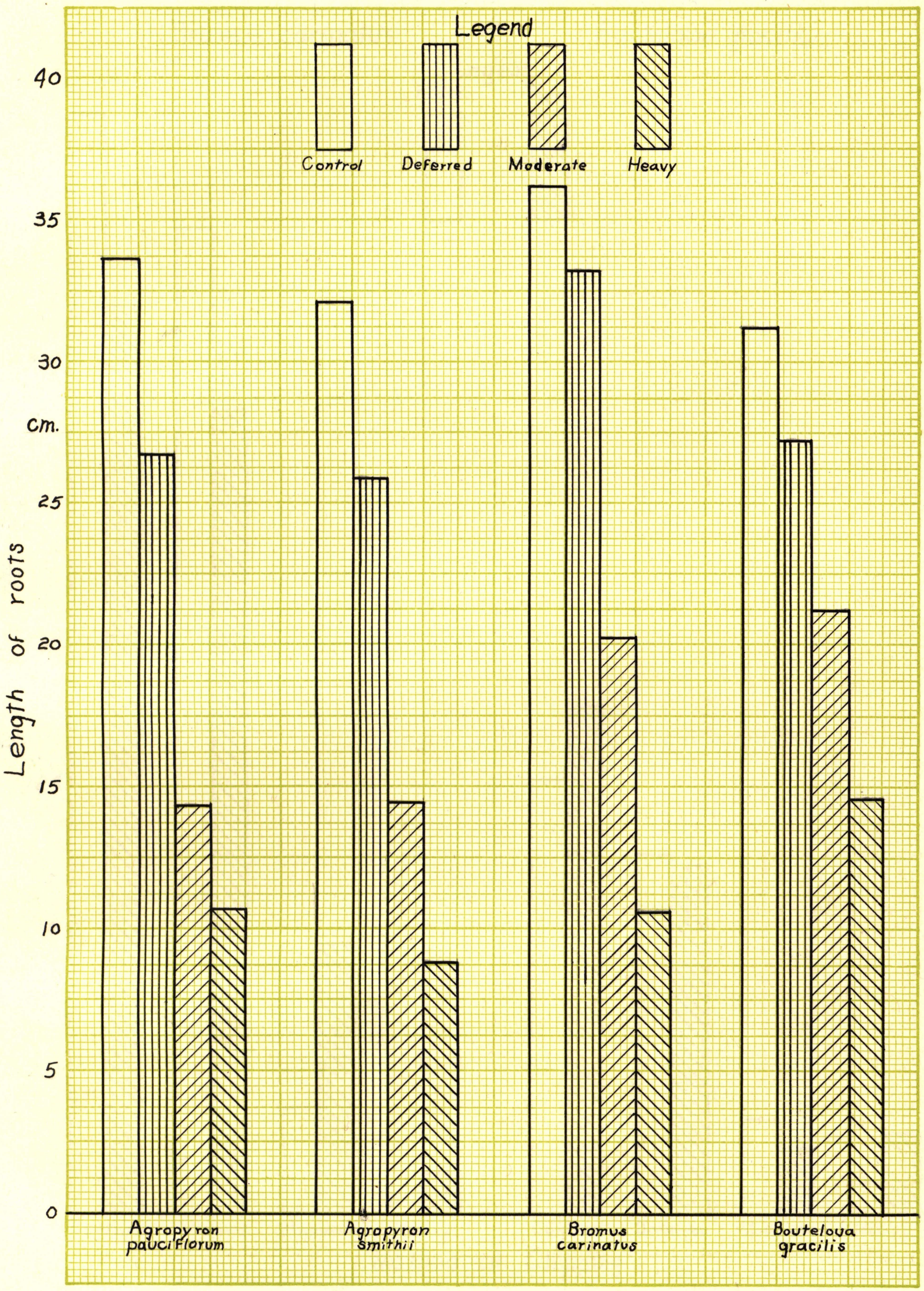


Fig. 9. Comparison of root lengths under different intensities of clipping in boxes.

Form E-4

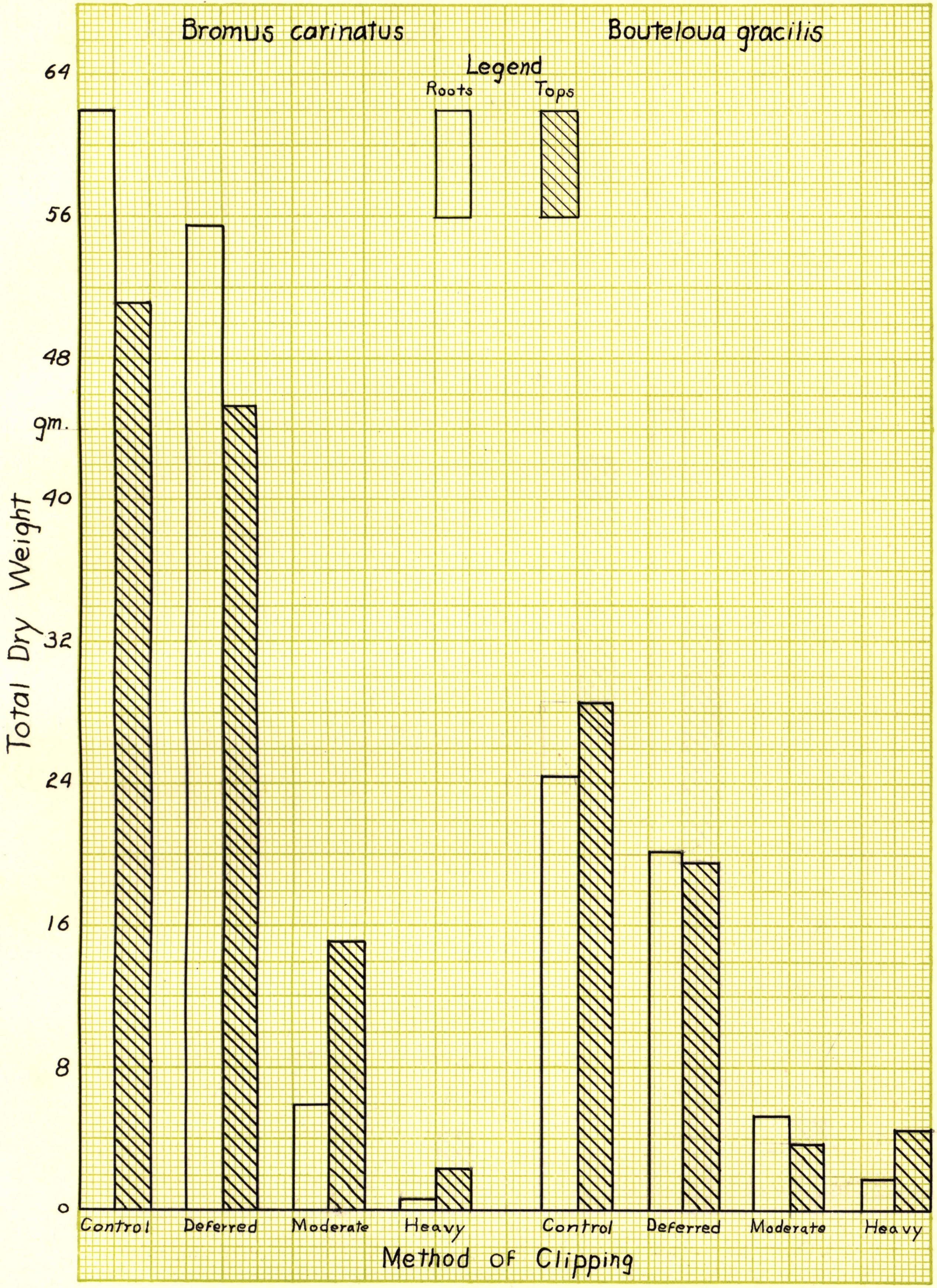


Fig. 10. Comparison of roots and tops under different methods of clipping in boxes.

Form E-4

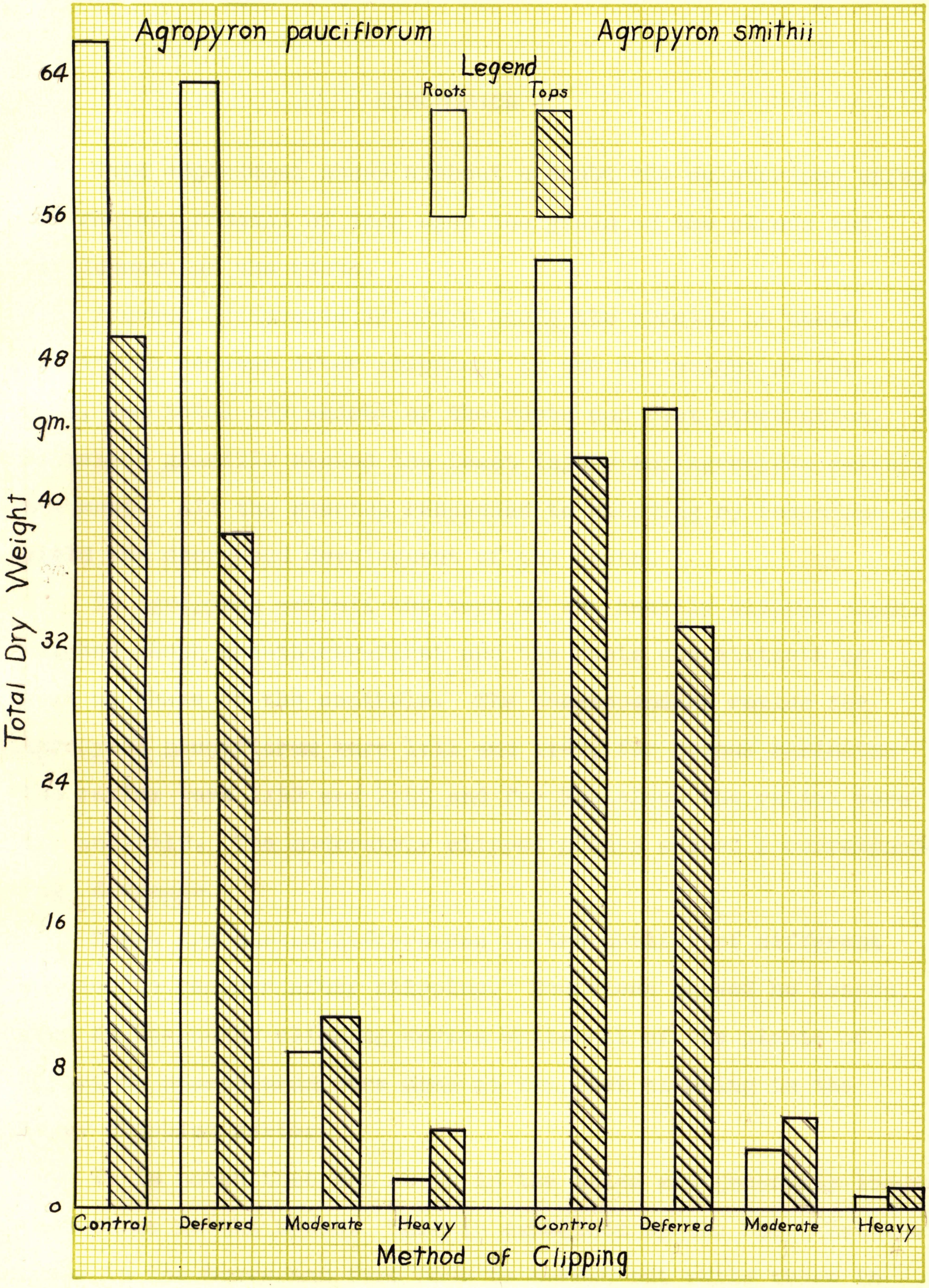


Fig. 11. Comparison of roots and tops under different methods of clipping in boxes.

DISCUSSION

This experiment shows without a doubt the deleterious effect of frequent removal of tops upon the yield of the plants and development of the roots.

A great difference is noted among the species in their ability to recover after clipping, in the dry weight of the tops, and total dry weight of the roots and root penetration. Bouteloua gracilis showed the least injury and Agropyron smithii the most. All the species responded to clipping by reduction in yield and decreased development of the roots.

In Agropyron smithii the tops of the heavily clipped plants weighed about one-thirty-first and the roots one-sixtieth as much as those of the controls. The corresponding ratios for Agropyron pauciflorum were 1:11 and 1:40; for Bromus carinatus the ratios were 1:23 and 1:85 and for Bouteloua the ratios were 1:6 and 1:12. The moderately clipped plants showed a corresponding decrease.

There are marked differences in the ability of different species to recover after clipping. Bouteloua showed no losses, even in the heavy clipping series while all of the plants of Agropyron pauciflorum were dead at the last clipping in the heavy clipping series.

It is noted that the roots in the tiles are generally longer than those in the boxes. This is explained by the fact that the roots in the boxes had more room to spread out while those in the tiles had to go more or less straight down. Also the tiles were slightly deeper than the boxes, which gave the roots a little more room to develop in length.

There is a direct relation between the frequent removal of tops and the weakened root systems. Plants which are weakened by frequent clipping are less efficient in absorbing water and plant nutrients. Hence they are more subject to drouth and extremes of heat and cold. They are not able to extend themselves to any extent, therefore they are unable to compete with invasion of undesirables. The yield of the forage is reduced and also the life of the plant is greatly shortened by overgrazing.

The plants that were subjected to the heavy clipping treatment would probably, with the exception of blue grama, die if subjected to winter cold or to drouth. They would have scarcely any food in reserve and with such a poor root system they would not be able to stand much cold or prolonged drouth. The plants that were only moderately clipped would probably come through winter cold or summer drouth with some plants surviving as they had a better root system and probably more food in reserve. In the deferred and control groups just about all of the plants should survive. From this it is very evident that if we are to be successful with either natural or artificial regeneration of grassland it must be protected from grazing until the seedlings have become well established.

Under the conditions of this experiment, blue grama showed far less injury than the other species subjected to the same treatment. The green area of the tops of blue grama extends practically to ground level, while in the other species it does not come so close to the ground, so after clipping there is more photosynthetic area left in the blue grama than there is in the others. In blue grama more photosynthetic area was left to continue food making, while in the other species the green area was almost completely removed at each clipping which put these plants at a great disadvantage. This fact probably explains why blue grama stands up so well under continuous early grazing on the range and why it is so valuable on year-long or season-long range.

SUMMARY AND CONCLUSIONS

1. The seeds of four important range grasses were grown in soil in the greenhouse for seventeen weeks.

2. Different intensities of clippings were used to simulate grazing. Plants were clipped every 10 days for heavy clipping, every 20 days for moderate clipping. The deferred clipping series received two clippings near the end of the experiment.

3. A study of the tops was made after each clipping for rate of growth and weight of dry matter produced. The roots were removed and studied at the end of the experiment for total dry weight and length.

4. Growth of tops decreased as a result of clipping. The yield was reduced from 84 per cent to 97 per cent of the control

in the heavy clipping,from 70 per cent to 88 per cent in the moderate clipping, and from 12 per cent to 30 per cent in the deferred clipping series for the different species.

5. The roots showed an even greater decrease as a result of clipping. There was a reduction in growth from 92 per cent to 98 per cent of the control in the heavy clipping, from 78 per cent to 93 per cent in the moderate clipping, and from 4 per cent to 20 per cent in the deferred clipping series for the different species.

6. The greatest reduction in yield occurred in Agropyron smithii and this was also accompanied by a great reduction in roots.

7. The least reduction of roots and tops occurred in Bouteloua gracilis.

8. Removal of the tops of grass seedlings had an injurious effect which was measurable both above and below ground. The seriousness of the injury depends largely upon the species and the frequency of clipping.

9. If reseeding is to be successful, it must be protected from grazing to obtain maximum development of roots and tops.

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